Write your name, centre number and candidate number in the boxes below.

Surname	Other names

Centre number | | | | | |

Candidate number | | | | |

STEM | Exam Builder

Reversible reactions and equilibrium

Time allowed: 1 hour 30 minutes

Subject code **0620**

Chemistry

Paper 4 (Extended)

You must have: a ruler marked in centimetres and millimetres, a protractor, compasses, a pen, an HB pencil and an eraser.

Total marks

/ 96

Instructions

- Answer every question in the space provided on this paper.
- Write in black or dark blue ink. Pencil may be used for diagrams and graphs.
- Fill in your name, centre number and candidate number above.
- Show your working: a correct method can earn marks even if the answer is wrong.

Information

- This paper has 10 questions worth 96 marks in total.
- The marks for each question or part are shown in brackets, for example [3].

Advice

- Read every question through once before you write anything.
- Use the marks in brackets to judge how long to spend on each part.
- If you finish early, go back and check your working.

STEM | Exam Builder

Print at 100% (Actual size) so diagrams keep their real measurements.

1 Ammonia is made by the Haber process.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

The forward reaction is exothermic.

Typical reaction conditions are:

- finely divided iron catalyst,
- temperature 450 °C,
- pressure 200 atmospheres.

(a) Explain why the catalyst is used as a very fine powder and larger pieces of iron are not used.

.....

.....

..... [2]

(b) Using the above conditions, the equilibrium mixture contains about 15% ammonia.

State two changes to the reaction conditions which would increase the percentage of ammonia at equilibrium.

.....

.....

..... [2]

(c) Suggest why the changes you have described in **(b)** are **not** used in practice.

.....

.....

..... [2]

[Total: 6]

Rates of reaction Click for more variations

STEM | Exam Builder

2 Iodine reacts with chlorine to form dark brown iodine monochloride.

$$I_2 + Cl_2 \rightarrow 2ICl$$

This reacts with more chlorine to give yellow iodine trichloride.
There is an equilibrium between these iodine chlorides.

$$\underset{\text{dark brown}}{ICl(l)} + Cl_2(g) \rightleftharpoons \underset{\text{yellow}}{ICl_3(s)}$$

(a) Explain what is meant by *equilibrium*.

.....

.....

..... [2]

(b) When the equilibrium mixture is heated it becomes a darker brown colour.
Is the reverse reaction endothermic or exothermic? Give a reason for your choice.

.....

.....

..... [2]

(c) The pressure on the equilibrium mixture is decreased.

(i) How would this affect the position of equilibrium and why?

It would move to the ..... [1]

reason .....

..... [1]

(ii) Describe what you would observe.

.....

..... [1]

[Total: 7]

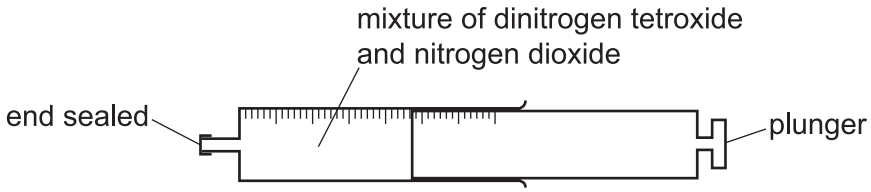
Reversible reactions and equilibrium Click for more variations

STEM | Exam Builder

3 Dinitrogen tetroxide, N_2O_4, decomposes into nitrogen dioxide, NO_2. The reaction is reversible.

$$\underset{\text{colourless gas}}{N_2O_4(g)} \rightleftharpoons \underset{\text{brown gas}}{2NO_2(g)}$$

A gas syringe containing a mixture of dinitrogen tetroxide and nitrogen dioxide gases was sealed and heated. After reaching equilibrium the mixture was a pale brown colour.



(a) State what is meant by the term *equilibrium*.

.....

.....

..... [2]

(b) The plunger of the gas syringe is pushed in. The temperature does not change. The mixture initially turns darker brown. After a few seconds the mixture turns lighter brown because the equilibrium shifts to the left.

$$\underset{\text{colourless gas}}{N_2O_4(g)} \rightleftharpoons \underset{\text{brown gas}}{2NO_2(g)}$$

(i) Explain why the mixture initially turns darker brown.

..... [1]

(ii) Explain why the position of equilibrium shifts to the left.

..... [1]

(c) The forward reaction is endothermic.

(i) State what happens to the position of equilibrium when the temperature of the mixture is increased.

..... [1]

(ii) State what happens to the rate of the forward reaction and the rate of the backward reaction when the temperature of the mixture is increased.

rate of the forward reaction .....

rate of the backward reaction .....

[2]

[Total: 7]

Reversible reactions and equilibrium Click for more variations

STEM Exam Builder

4 Ammonia is an important industrial chemical.

(a) (i) Give the electron structure of an atom of nitrogen.

..... [1]

(ii) Use this electronic structure, rather than the valency of nitrogen, to explain why the formula of ammonia is NH_3 not NH_4.

.....

.....

..... [2]

(b) Ammonia is made by the Haber Process.

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ forward reaction is exothermic

The percentage of ammonia in the equilibrium mixture varies with conditions.

pressure / atmospheres	100	200	300	400
% ammonia at 300 °C	45	65	72	78
% ammonia at 500 °C	9	18	25	31

The conditions actually used are 200 atmospheres, 450 °C and an iron catalyst.

(i) The original catalyst was platinum. Suggest a reason why it was changed to iron.

..... [1]

(ii) Explain why the highest pressure gives the highest percentage of ammonia in the equilibrium mixture.

.....

..... [2]

(iii) What happens to the unreacted nitrogen and hydrogen?

.....

..... [1]

(iv) State **one** advantage and **one** disadvantage of using a lower temperature.

advantage .....

..... [1]

disadvantage .....

..... [1]

[Total: 9]

STEM | Exam Builder

Covalent bonding and simple molecules Click for more variations

5 Hydrogen iodide thermally decomposes into iodine and hydrogen. The reaction is reversible.

$$\underset{\text{colourless gas}}{2HI(g)} \rightleftharpoons \underset{\text{purple gas}}{I_2(g)} + \underset{\text{colourless gas}}{H_2(g)}$$

Fig. 4.1 shows a gas syringe containing a mixture of hydrogen iodide, iodine and hydrogen gases. The gas syringe is sealed and the mixture is heated to 300 °C. The mixture of gases reaches equilibrium and is purple.

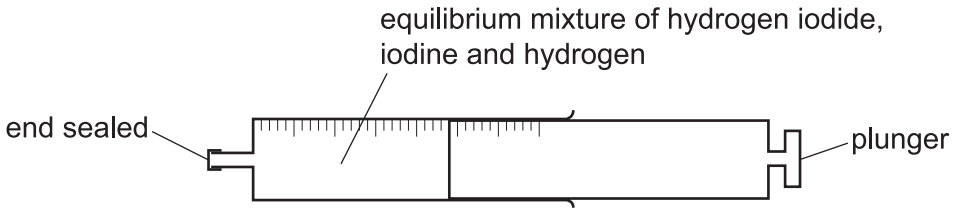


Fig. 4.1

(a) State what is meant by the term equilibrium.

.....

.....

..... [2]

(b) The pressure of the mixture is increased. All other conditions stay the same. The position of equilibrium does **not** change.

The colour of the gaseous mixture turns darker purple.

The temperature remains constant.

$$\underset{\text{colourless gas}}{2HI(g)} \rightleftharpoons \underset{\text{purple gas}}{I_2(g)} + \underset{\text{colourless gas}}{H_2(g)}$$

(i) Explain why the position of equilibrium does **not** change.

.....

..... [1]

(ii) Suggest why the colour of the mixture of gases turns darker purple.

.....

..... [1]

STEM | Exam Builder

(c) The temperature of the mixture of gases is decreased. All other conditions stay the same.

The mixture of gases turns lighter purple.

State what can be deduced about the forward reaction from this information.

..... [1]

(d) Deduce the oxidation number of iodine, I, in:

HI .....

I_2. .....

[2]

(e) Methanol is manufactured by reacting carbon monoxide with hydrogen.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g)$$

The rate of formation of methanol increases when a catalyst is used.

(i) Choose from the list the element that is most likely to be used as the catalyst.

Draw a circle around your chosen answer.

calcium **carbon** **copper** **sodium** **sulfur** [1]

(ii) State the effect on the position of equilibrium when a catalyst is used.

..... [1]

(iii) State the effect that a catalyst has on the activation energy, E_a, of a reaction.

..... [1]

[Total: 10]

Reversible reactions and equilibrium Click for more variations

STEM | Exam Builder

6 Some chemical reactions are reversible.

(a) Aqueous potassium chromate(VI), K_2CrO_4, is a yellow solution.

Aqueous potassium dichromate(VI), $K_2Cr_2O_7$, is an orange solution.

The two compounds interconvert when the pH of the solution changes.

$$\underset{\text{yellow}}{2K_2CrO_4} + H_2SO_4 \rightleftharpoons \underset{\text{orange}}{K_2Cr_2O_7} + K_2SO_4 + H_2O$$

Solution **Y** is a mixture of aqueous potassium chromate(VI) and aqueous potassium dichromate(VI) at equilibrium.

- Explain, in terms of the position of the equilibrium, what you would **see** if sulfuric acid were added to solution **Y**.

.....

.....

.....

- Explain, in terms of the position of the equilibrium, what you would **see** if sodium hydroxide were added to solution **Y**.

.....

.....

.....

.....

[5]

STEM | Exam Builder

(b) Hydrogen can be manufactured using a reversible reaction between methane and steam.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g)$$

At 900 °C, in the presence of a nickel catalyst, the yield of hydrogen is 70%.

(i) What volume of hydrogen is produced from 100 cm^3 of methane under these conditions?

..... cm^3 [2]

Under different conditions, different yields of hydrogen are obtained.

(ii) If the pressure is increased, the yield of hydrogen becomes less than 70%.

Explain why, in terms of the position of the equilibrium.

.....

..... [1]

(iii) If the temperature is decreased, the yield of hydrogen decreases.

What does this information indicate about the reaction between methane and steam?

..... [1]

(iv) Why is a catalyst used in this reaction?

..... [1]

[Total: 10]

STEM | Exam Builder

Reversible reactions and equilibrium Click for more variations

7 Reversible reactions can come to equilibrium. The following are three examples of types of gaseous equilibria.

$A_2(g) + B_2(g) \rightleftharpoons 2AB(g)$ **reaction 1**

$A_2(g) + 3B_2(g) \rightleftharpoons 2AB_3(g)$ **reaction 2**

$2AB_2(g) \rightleftharpoons 2AB(g) + B_2(g)$ **reaction 3**

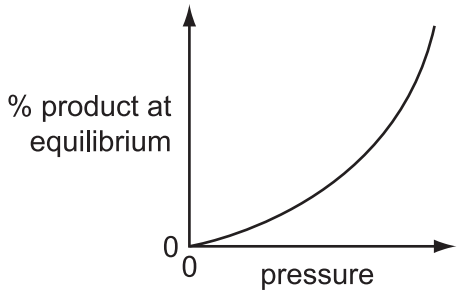
(a) Explain the term *equilibrium*.

.....

..... [2]

(b) The following graphs show how the percentage of products of a reversible reaction at equilibrium could vary with pressure.
For each graph, decide whether the percentage of products decreases, increases or stays the same when the pressure is **increased**, then match each graph to one of the above reactions and give a reason for your choice.

(i)



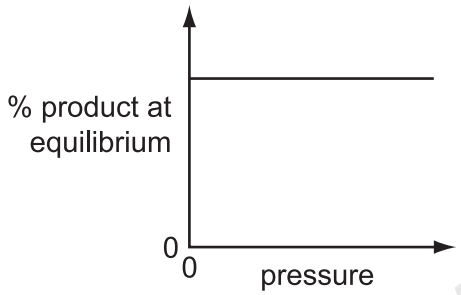
effect on percentage of products .....

reaction .....

reason .....

..... [3]

(ii)



effect on percentage of products .....

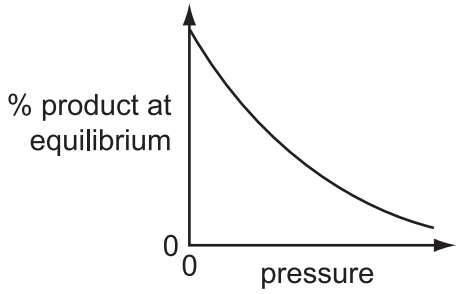
reaction .....

reason .....

..... [3]

STEM | Exam Builder

(iii)



effect on percentage of products .....

reaction .....

reason .....

..... [3]

[Total: 11]

Reversible reactions and equilibrium Click for more variations

STEM | Exam Builder

8 This question is about ammonia.

(a) Nitrogen reacts with hydrogen to form ammonia in an industrial process.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

(i) Name this industrial process.

..... [1]

(ii) State the meaning of the symbol $\rightleftharpoons$.

..... [1]

(iii) State the conditions used in this industrial process. Include units.

temperature .....

pressure .....

[2]

(iv) Name the catalyst used in this industrial process.

..... [1]

(v) If the pressure is increased, the yield of ammonia increases.

Explain why, in terms of equilibrium.

.....

.....

..... [2]

(vi) If the temperature is increased, the rate of reaction increases.

Explain why, in terms of particles.

.....

.....

.....

.....

..... [3]

(b) Ammonia reacts with sulfuric acid to make a compound which is used as a fertiliser.

Write the chemical equation for the reaction between ammonia and sulfuric acid.

..... [2]

[Total: 12]

Haber process and Contact process Click for more variations

STEM | Exam Builder

9 Methane reacts with steam to produce hydrogen gas.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \qquad \Delta H = +200\,kJ/mol$$

The reaction takes place at 1000 °C and 100 kPa pressure.

(a) The reaction is reversible and reaches an equilibrium in a closed system.

State **two** features of an equilibrium.

1 .....

2 .....

[2]

(b) State and explain, in terms of equilibrium, what happens to the concentration of hydrogen when:

(i) the pressure is increased

.....

..... [2]

(ii) the temperature is increased

.....

..... [2]

(iii) a catalyst is used.

.....

..... [2]

(c) Methane is a greenhouse gas which contributes to global warming.

(i) Name a greenhouse gas found in clean, dry air.

..... [1]

(ii) Explain, in terms of thermal energy, how greenhouse gases cause global warming.

.....

.....

.....

.....

..... [3]

[Total: 12]

Air, pollution and climate change Click for more variations

STEM | Exam Builder

10 Chalcopyrite, $FeCuS_2$, is used in the manufacture of sulfuric acid in the Contact process.

(a) In the first stage of the process, chalcopyrite reacts with oxygen in the air to produce sulfur dioxide, SO_2, iron(III) oxide and copper(II) oxide.

Complete the chemical equation for the reaction of $FeCuS_2$ with oxygen.

$$4FeCuS_2 + 13O_2 \rightarrow \text{.....} + \text{.....} + \text{.....}$$ [2]

(b) Sulfur dioxide is then converted to sulfur trioxide.

$$2SO_2 + O_2 \rightleftharpoons 2SO_3$$

The reaction is exothermic. It is also an equilibrium.

(i) State **two** features of an equilibrium.

1 .....

2 .....
[2]

(ii) State the temperature and pressure used in this reaction.
Include units.

- temperature .....
- pressure .....
[2]

(iii) Name the catalyst used.

..... [1]

(iv) Explain why a catalyst is used.

..... [1]

(v) Describe and explain, in terms of equilibrium, what happens when the temperature is increased.

.....

..... [2]

(c) Concentrated sulfuric acid is a dehydrating agent.

When glucose is dehydrated, carbon and one other product are formed.

Complete the equation to show the dehydration of glucose, $C_6H_{12}O_6$.

$$C_6H_{12}O_6 \rightarrow \text{.....}C + \text{.....}$$ [2]

[Total: 12]

Haber process and Contact process Click for more variations

STEM | Exam Builder